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Eriksson

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(54) **CHROMATOGRAPHY COLUMN AND MAINTENANCE METHOD**

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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B01D 15/10 (2006.01)

G01N 30/56 (2006.01)

G01N 30/60 (2006.01)

(52) **U.S. Cl.**

CPC **B01D 15/22** (2013.01); **B01D 15/10** (2013.01); **G01N 30/56** (2013.01); **G01N 30/6017** (2013.01); **Y10T 29/49718** (2015.01)

(58) **Field of Classification Search**

CPC B01D 15/22; B01D 15/10; G01N 30/6017; G01N 30/56; Y10T 29/49718

USPC 210/635, 656, 659, 198.2; 95/82; 96/101

See application file for complete search history.

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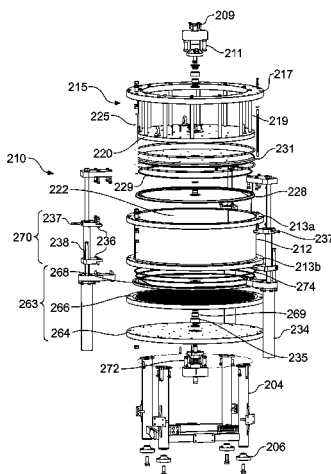
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(57) **ABSTRACT**

A chromatography column and method of maintenance is described which does not require the use of a hoist or crane for disassembly. The method provides improved operator safety by reducing the need for the operator to work below a suspended or supported load within the column. Furthermore, the removal or replacement of column components is facilitated by providing access to the interior of the column and by the provision of a handling device.

12 Claims, 18 Drawing Sheets



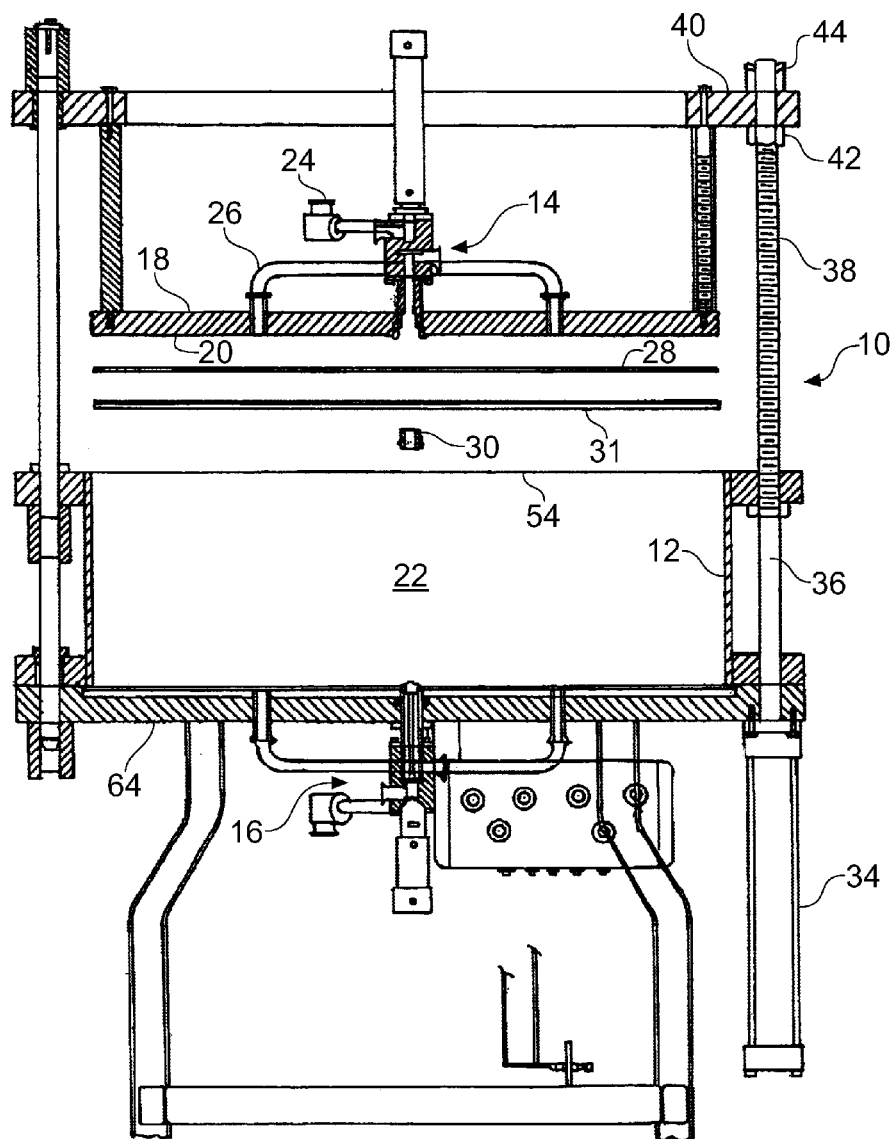


Fig. 1

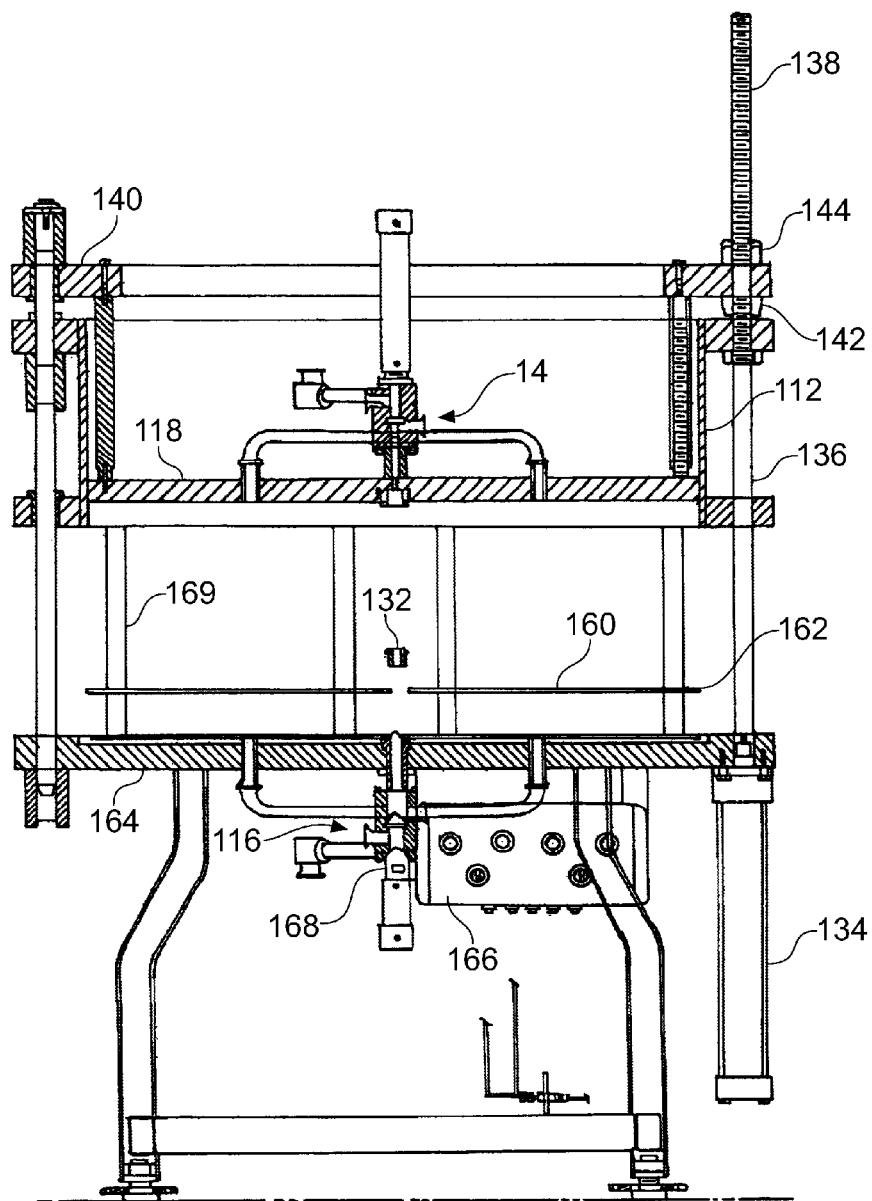


Fig. 2

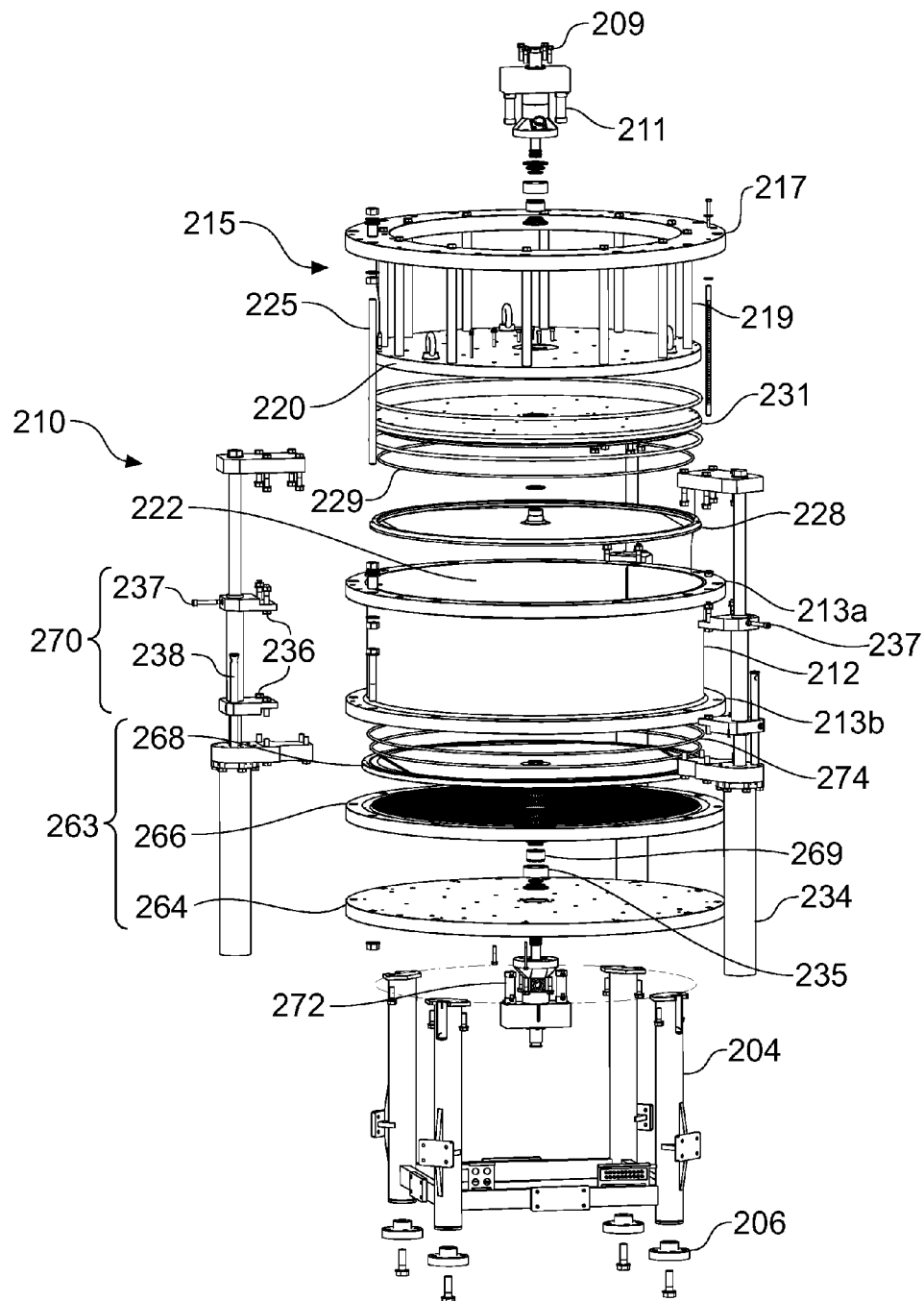


Fig. 3

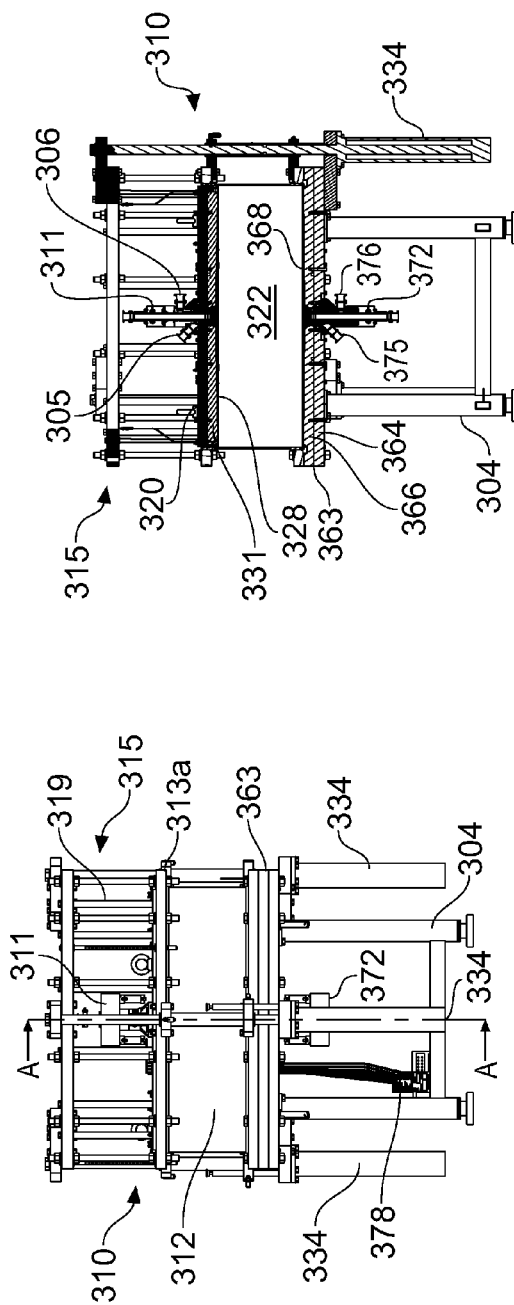


Fig. 4b

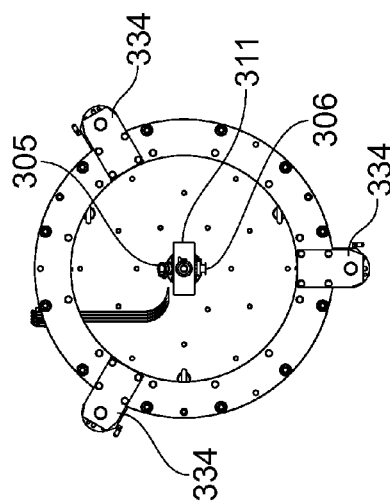


Fig. 4c

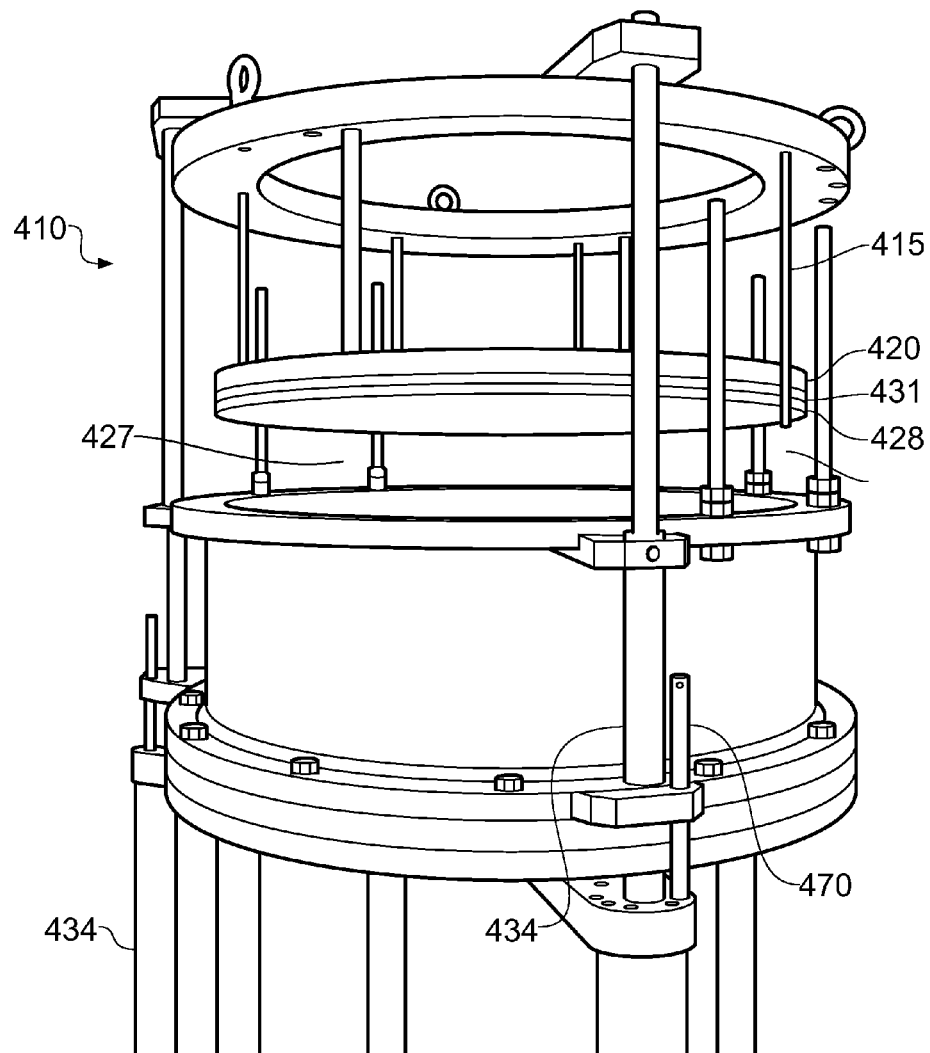


Fig. 5a

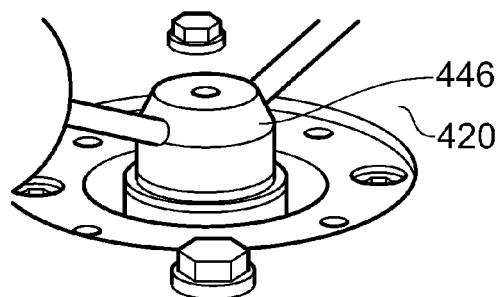


Fig. 5b

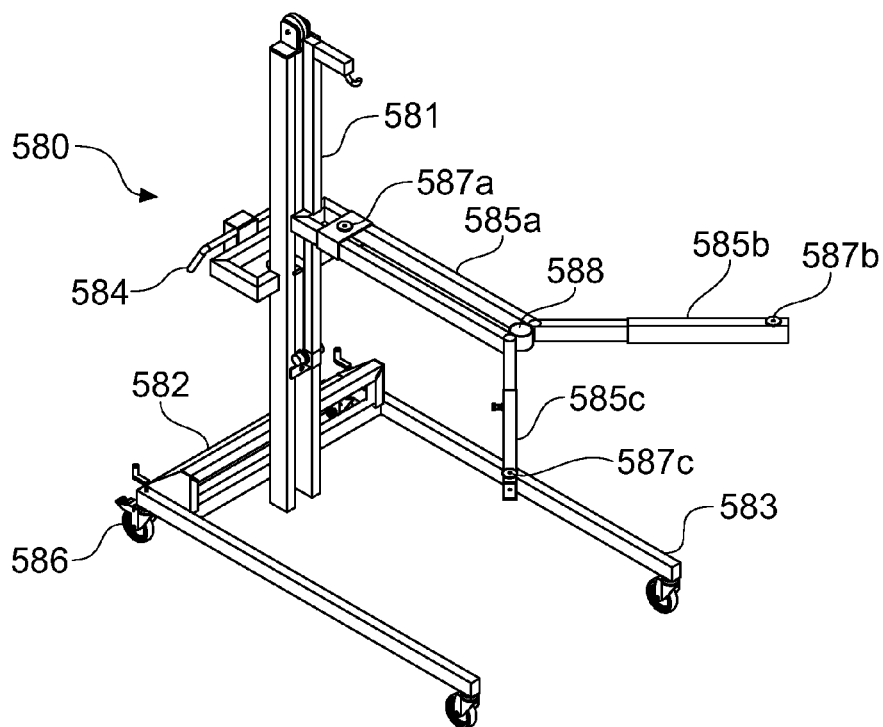


Fig. 6

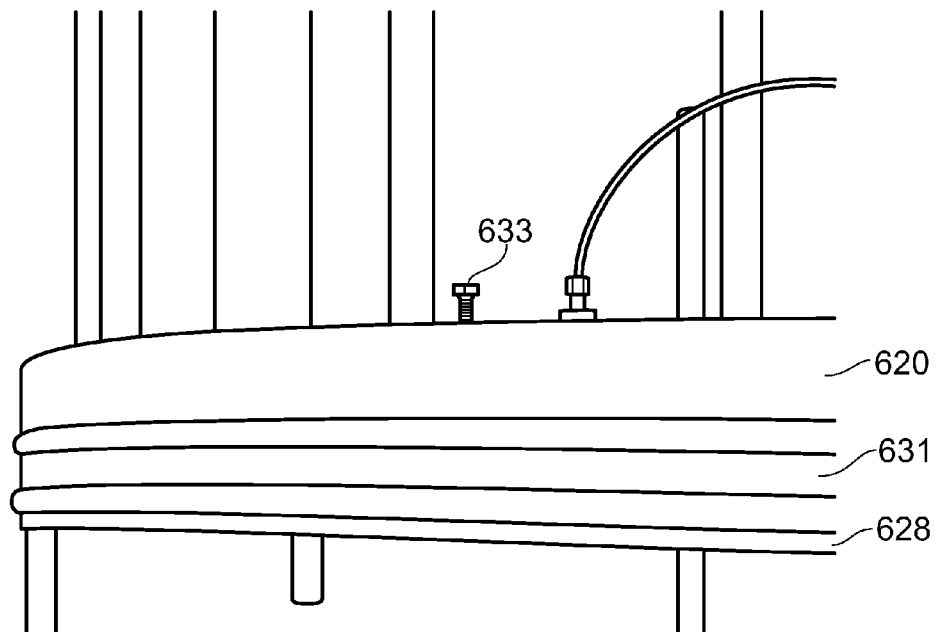


Fig. 7a

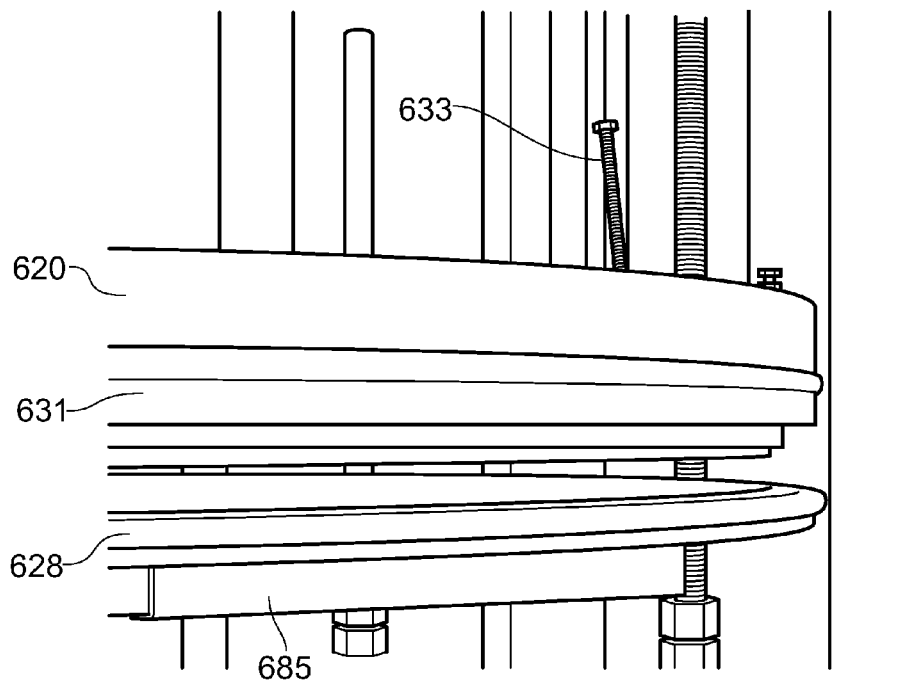


Fig. 7b

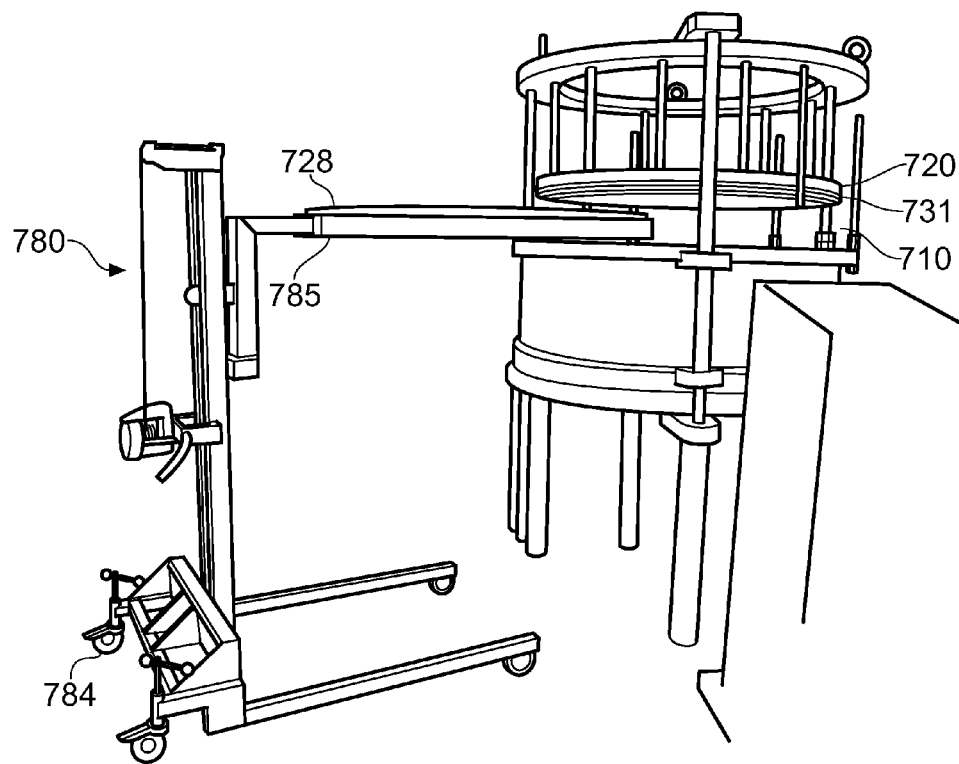


Fig. 8a

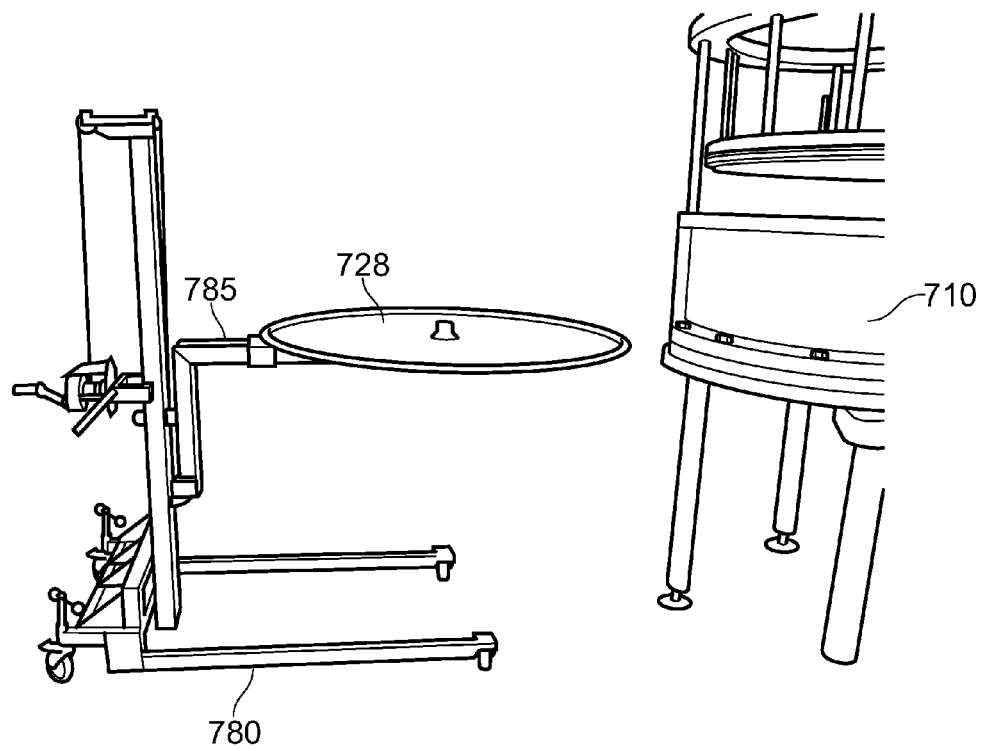


Fig. 8b

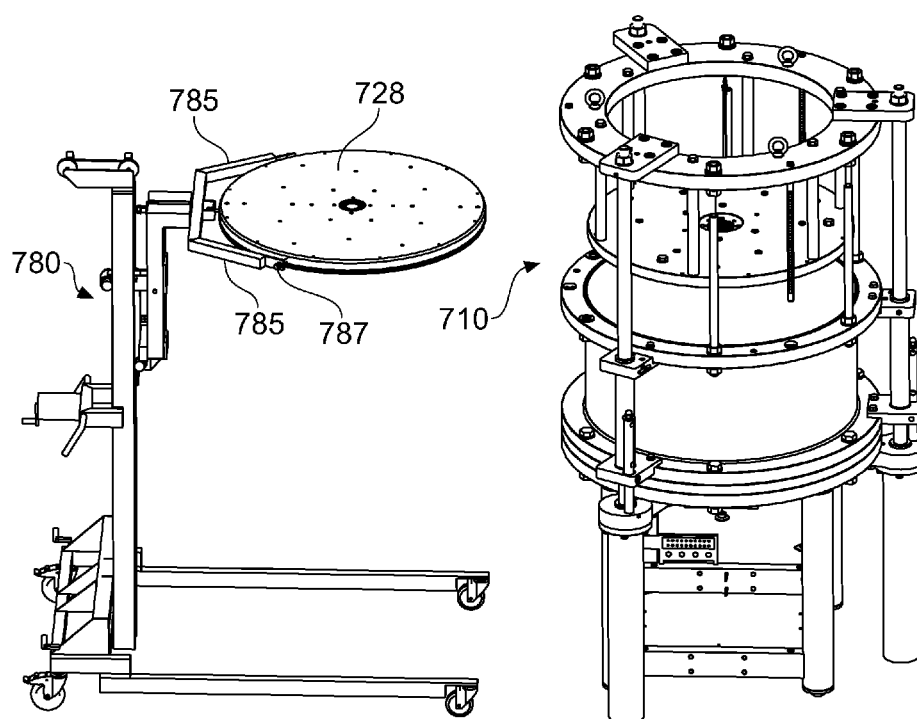


Fig. 8c

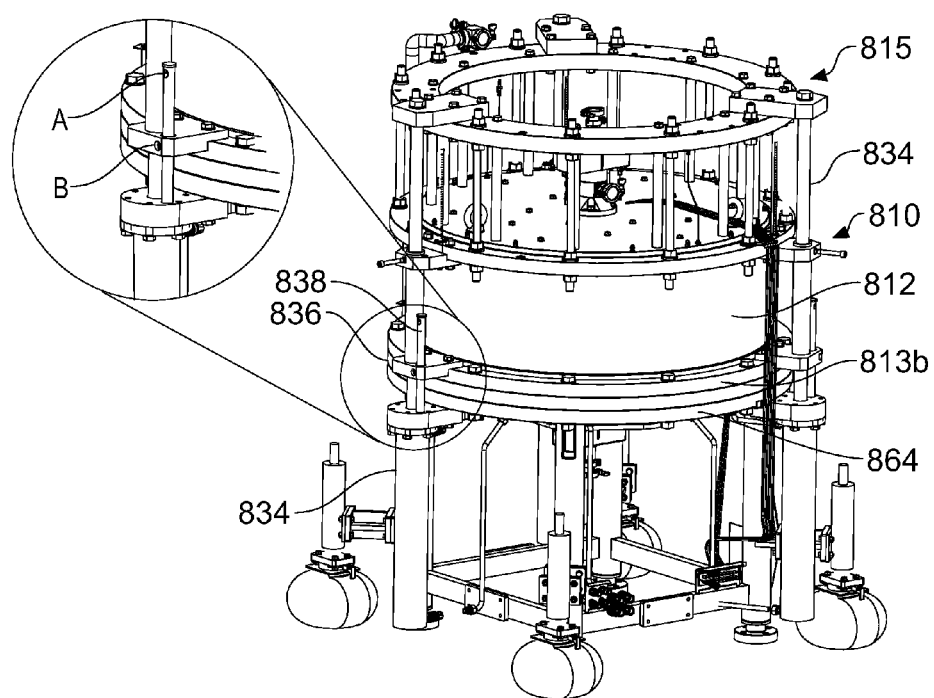


Fig. 9a

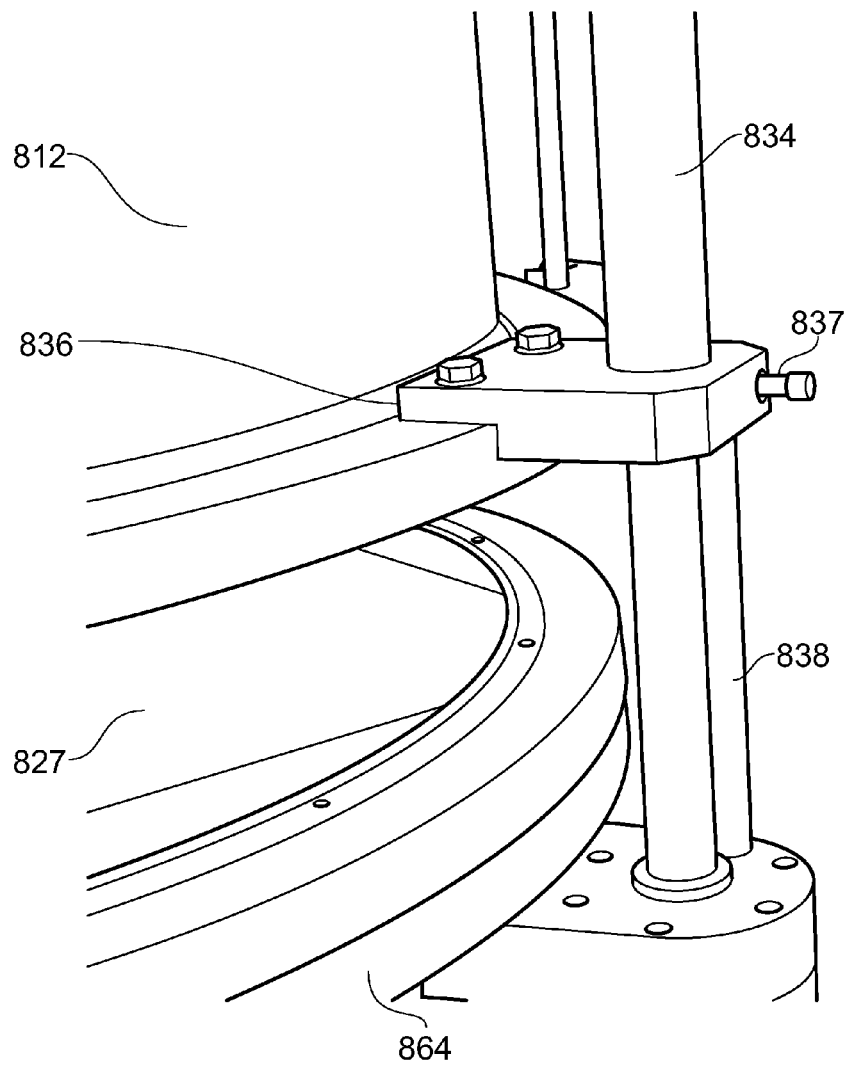


Fig. 9b

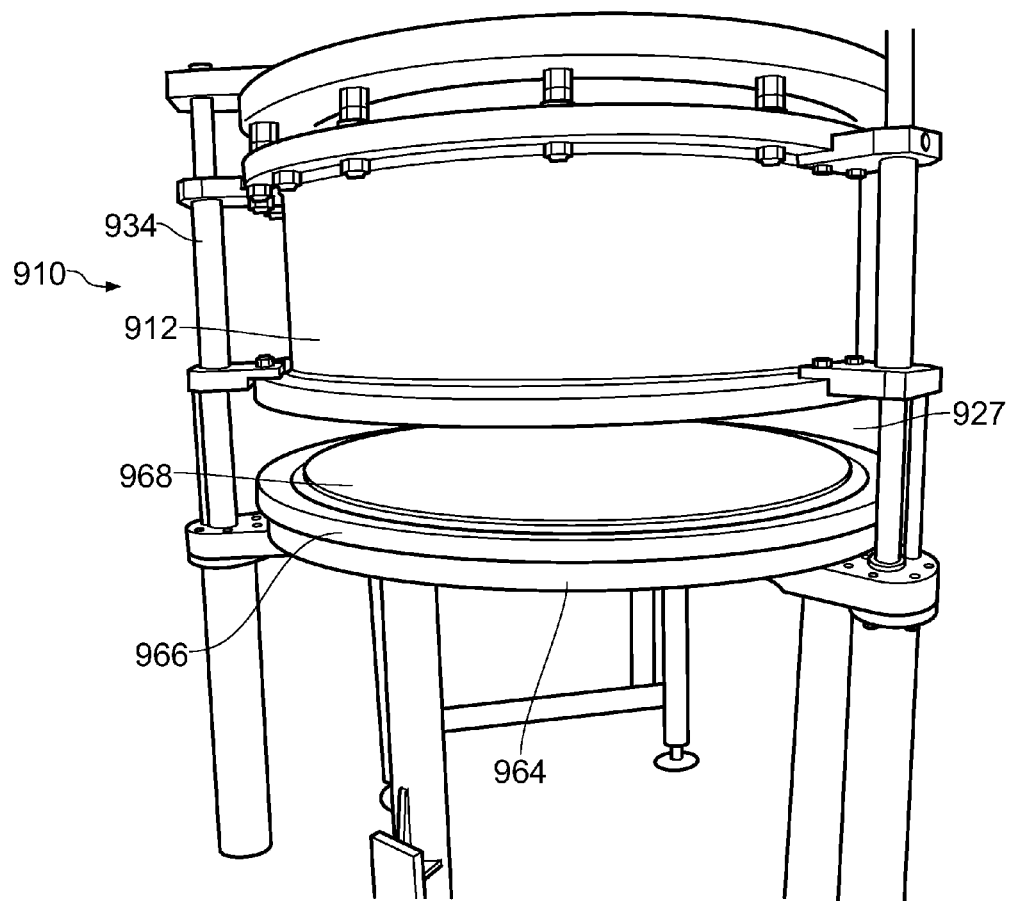


Fig. 10

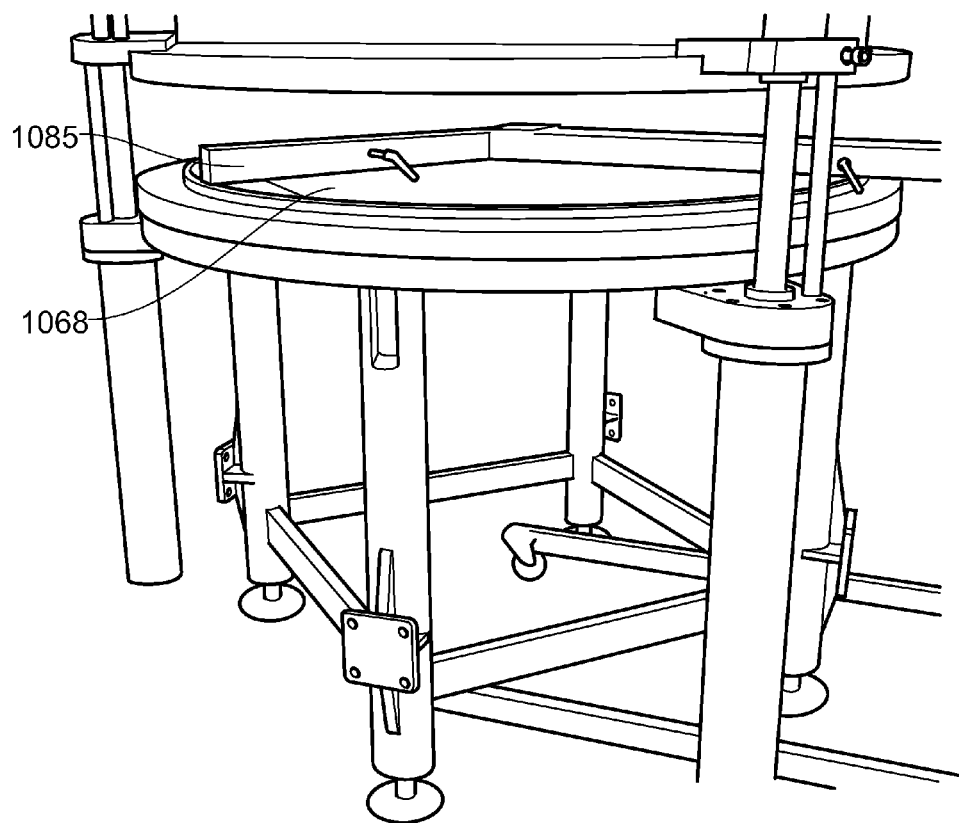


Fig. 11a

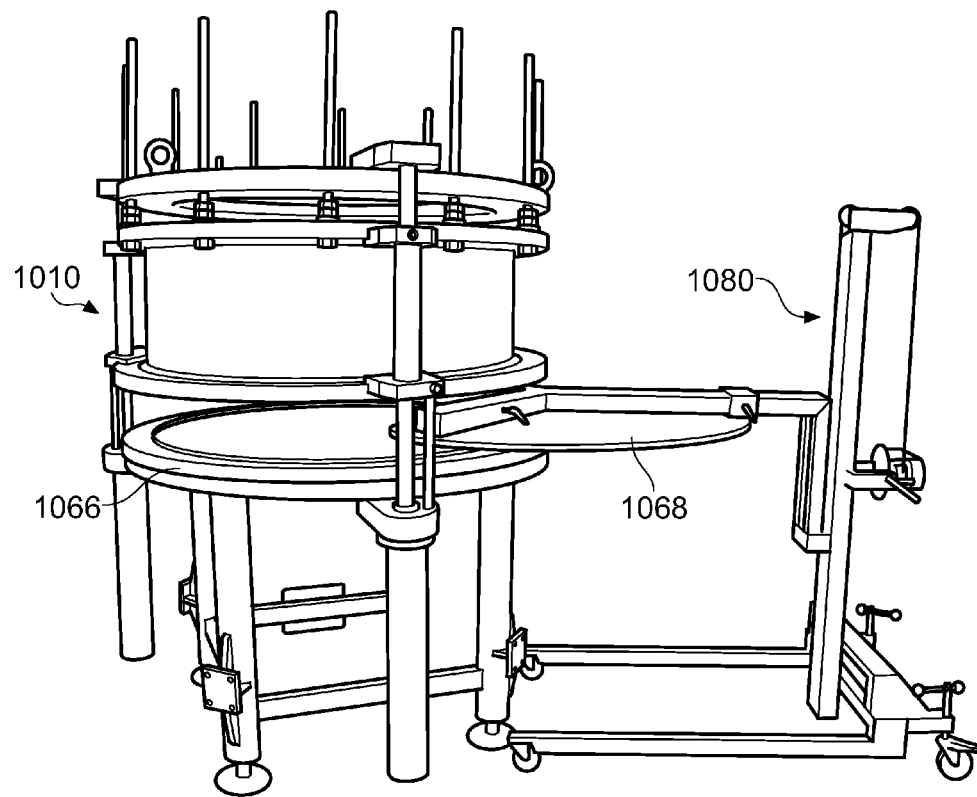


Fig. 11b

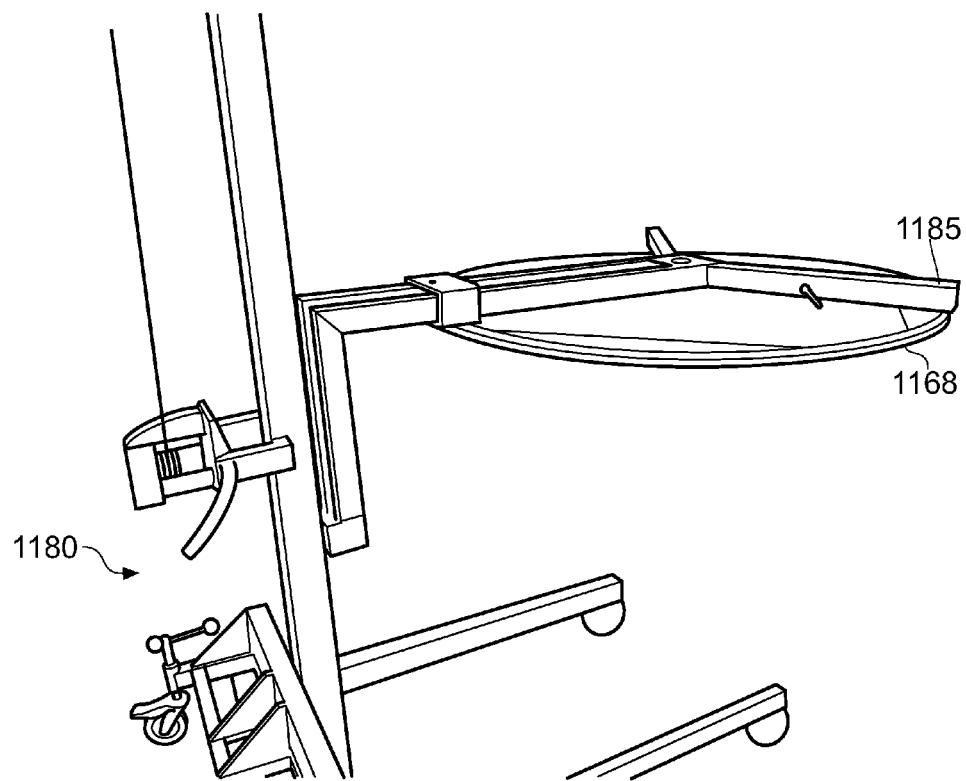


Fig. 12

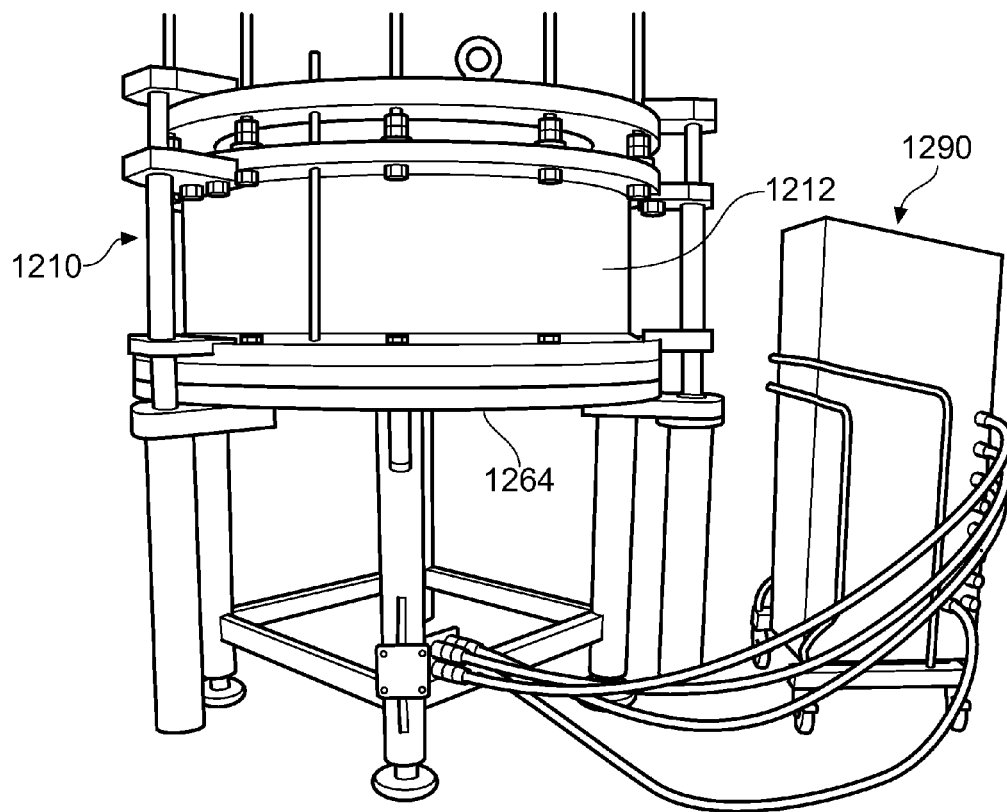


Fig. 13

CHROMATOGRAPHY COLUMN AND MAINTENANCE METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional filing of U.S. patent application Ser. No. 12/863,190 filed Jul. 16, 2010, now U.S. Pat. No. 8,394,276, which is a filing under 35 U.S.C. §371 and claims priority to international patent application number PCT/SE2009/000011 filed Jan. 15, 2009, published on Jul. 30, 2009, as WO 2009/093952, which claims priority to patent application number 0801212.2 filed in Great Britain on Jan. 23, 2008.

FIELD OF THE INVENTION

The present invention relates to chromatography columns and methods for operating columns in industrial-scale chromatography. In particular, the invention is concerned with chromatography columns and safer methods for performing maintenance on such columns, such as cleaning and replacing bed supports, distributors and O-rings, without the need for heavy lifting equipment such as hoists or cranes to dismantle the columns.

BACKGROUND OF THE INVENTION

Chromatography columns may be used in industrial processes to purify process liquids and separate substances of interest from process liquids; typical examples include large-scale preparative purification of fine chemicals and pharmaceuticals, together with biological products.

Industrial-scale chromatography columns typically comprise a hollow, axially vertical tubular housing including a liquid inlet at the upper end and through which the buffer and substances to be separated are dispensed to the media bed located within the cavity of the tube, and a liquid collecting system at the lower end for collecting substances and buffer. The particulate chromatographic media or bed through which the buffer fluid and/or substances to be separated and purified percolates is located between the liquid inlet and collecting system.

An adapter assembly is typically affixed to the upper end of the tubular housing and a base assembly to the lower end where it is bolted to the bottom flanges. Each of these assemblies typically comprises a strong backing plate and a distributor which further supports a bed support: a bed support is a layer of mesh, filter, sinter, screen or other fluid-permeable media-retaining material which permits process liquid flow into and out of the chromatography bed space or cavity while retaining the bed of particulate medium. To provide adjustability and control of the bed height and bed compression, the adapter assembly is typically made in the form of a piston or sliding adapter in the column tube interior. After the column is charged with bed media, typically through a nozzle, the adapter may be forced toward the bottom of the tube to compress or pressurize the media bed. Generally the base assembly is a fixed structure which is bolted against the bottom flange of the column tube but, in some instances, may also be in the form of a movably slidable piston or adapter.

The backing plate of the base assembly generally acts as a support for the column, being itself supported on legs or some other stand arrangement which allows clearance for outlet pipe work projecting beneath the base assembly.

When such a column requires maintenance to, or cleaning of, internal components, such as the valves, seals, meshes/

screens, distribution systems etc., heavy lifting gear such as a crane or hoist is necessary to lift the upper end/adapter assembly away from the column tube and the column tube away from the lower end/base assembly as these assemblies can weigh in excess of three tons. The use of heavy overhead lifting equipment to disassemble the column in order to carry out internal maintenance is not desirable. Operator safety is obviously a concern when heavy equipment is lifted overhead and technicians exposed below. Furthermore, alignment structures are required to keep the column and its base/adapter assemblies axially aligned as they are separated from each other, to avoid damage to the precision components.

The presence of such alignment and lifting structures imposes significant obstructions around the tube and need to be carefully laid out to provide sufficient clearance at some point of the circumference for insertion/removal of the internal components. Furthermore, the requirement to use heavy lifting equipment imposes constraints on housing such columns, sufficient overhead space and support being required to accommodate hoists or cranes. As many chromatography columns are now run in "clean" environments under GMP, to avoid microbiological contamination, where it is extremely difficult to accommodate overhead equipment, the requirement of moving the column to another room for disassembly and maintenance is problematic. This problem is exacerbated by the need to clean and verify the column before returning it for use to the clean environment. The presence of hoists or cranes in GMP facilities used for biopharmaceutical manufacturing is thus highly undesirable for the above mentioned reasons, together with the fact that these machines shed particulate matter, in the form of dirt, during their operation and maintenance.

U.S. Pat. No. 6,736,974 addresses some of the above problems by providing a column which is capable of lifting the adapter assembly above the column tube and/or raising the column tube above the base assembly by means of an hydraulic system which is integral to the column.

However, the system described in U.S. Pat. No. 6,736,974 has significant disadvantages associated with it by virtue of its design. As can be seen from FIGS. 4 and 5 of U.S. 6,736,974 and described in column 4, lines 63-66 of that document, in order to remove the distributor plate (31) and/or mesh (28/60) from the interior of the column, the operator must work within the centre of the drum (18) to access and remove the fixing nut (30) which secures these component parts. As industrial columns typically have diameters ranging from about 200 mm to 2000 millimeters, this means that the operator must work below a suspended or supported load to unscrew the nut. This clearly poses a significant safety risk to the operator, particularly where the operator's arm or head is exposed below the suspended or supported load.

Furthermore, once the column tube/cylinder or adapter assembly has been raised from the base assembly or tube, respectively, removal of the heavy bed support and/or distributor from the column can only be accomplished by tilting the bed support or distributor at an angle to negotiate the hydraulic drive pistons or safety rods. This can clearly be seen from, for example, FIGS. 3, 4 and 5 in which the distance between any two safety rods (69) or between any two hydraulic pistons (36) is less than the diameter of the mesh (28/60) or distributor plate (31). The same problem would exist for the base or adapter bed support (not shown). Removal of these internal components, which could weigh in excess of 100 kg, requires considerable manhandling by the operator and necessitates their being exposed below the suspended column or adapter assembly. Once again, this represents a significant safety risk for the operator.

The task of physically removing the heavy bed support or distributor, as described in U.S. Pat. No. 6,736,974, must be carried out by an operator, there being no disclosure of the use of any lifting aid to assist in this task. The configuration of the hydraulic pistons and the safety rods, and the need to tilt the bed support and/or distributor in order to avoid hitting these supporting structures in withdrawing these components from the column, would require the design of a bespoke lifting device.

Furthermore, the method described in U.S. Pat. No. 6,736,974, necessitates raising the column tube/cylinder or adapter assembly from the base assembly or tube, respectively, a predetermined distance greater than three inches in order to carry out maintenance of the column, distances greater than six inches and most preferably about twelve inches being specified.

WO 2005/056156 (Euroflow (UK) Limited) also discloses a column which can be accessed for maintenance without the need for a crane or hoist. The column is designed such that the tube and the base assembly can be separated by means of hydraulic drive cylinders to provide an access space between them to conduct maintenance or service on the base assembly. The piston of the adapter assembly can be advanced through the column tube to expose it at the open end of the column tube, i.e. in the space between the tube and the base assembly, for maintenance.

However, as is evident from this document (for example, FIGS. 19 and 20 and related description on page 23) access to release the fastening screws retaining the bed support or mesh in place is provided by the space between the tube and the base assembly. Removal of the bed support necessitates the operator being exposed to a suspended load while retaining screws are removed. Furthermore, the distance between any two drive cylinders for maintenance access is less than the diameter of the bed support (see, for example, FIG. 7), which requires the operator to manhandle and tilt the bed support when removing or replacing it. Maintenance of the column thus imposes a significant safety risk for the operator.

Accordingly, a need exists to improve the maintenance methods available for chromatography columns by providing columns which are safer and easier for operators to use and which do not expose them to a suspended or supported load, thereby reducing the risk of operator error and injury.

SUMMARY OF THE INVENTION

The present invention recognises and addresses these needs and others.

In a first aspect of the present invention, there is provided a method for conducting maintenance on a chromatography column comprising the steps of:

- a) providing a chromatography column comprising;
 - a dispersion system comprising a nozzle including a mobile phase pathway connected to a liquid inlet;
 - a tube with an adapter assembly connected to a drive system, said adapter assembly moveable within a cavity of said tube in an operational mode;
 - the adapter assembly comprising a distributor and a bed support fastened to each other by releasable fixing means,
 - said drive system comprising one or more cylinders;
 - a collection system opposing the dispersion system; and
 - one or more seals;

- b) disconnecting the adapter assembly from the tube;
- c) lifting the adapter assembly a distance of no more than three inches or seventy six millimeters above the tube with the drive system to provide a gap for access therebetween;
- d) unfastening the bed support from the distributor by releasing the fixing means without accessing said gap;
- e) removing the bed support from the column;
- f) conducting maintenance on the column and/or the bed support and/or said one or more seals;
- g) returning the bed support to the column and fastening the bed support to the distributor; and
- h) lowering the adapter assembly with the drive system to an operational position within the tube and reconnecting the adapter assembly to the tube.

The gap provided for access between the adapter assembly and the tube is no more than three inches or seventy six millimeters in height in order to permit removal of the bed support from the column or return thereto. In one aspect, the gap is no more than two inches or fifty millimeters in height to allow access to the column. In another aspect, the gap is less than two inches or fifty millimeters in height. In a further aspect, the gap is less than one inch or twenty five millimeters in height. In yet another aspect the gap is at least 0.4 inches or 10 millimeters in height. Restriction of the gap height to less than three inches or seventy six millimeters prevents the operator from working beneath the raised adapter assembly and being physically exposed to the suspended weight.

In a preferred aspect, the fixing means are releasable from the exterior face of the distributor. This further reduces the exposure of the operator to a suspended or supported load as they do not need to enter the gap.

In a particularly preferred aspect, the drive system comprises at least two cylinders and the distance between any two said cylinders for maintenance access is greater than the diameter of the bed support. This permits the use of a handling device to support and remove or replace the bed support and/or distributor from/to the column.

Preferably cylinders are externally mounted to the column. This facilitates greater spacing between the cylinders. More preferably, each said cylinder is independently removable from the column.

Preferably, the step of removing the bed support is carried out without substantially tilting the bed support. This reduces operator exposure beneath the suspended load and facilitates manhandling and/or mechanical handling of the bed support. The term 'without substantially tilting' as used herein means 'tilting at an angle of no more than 5° to the horizontal'.

More preferably, the step of removing the bed support involves use of a handling device. More preferably, the handling device comprises at least one arm and the method comprises supporting the bed support on or affixing the bed support to at least one arm of the handling device.

Optionally, the step of conducting maintenance on the column further comprises removing the distributor without substantially tilting said distributor. The term 'without substantially tilting' as used herein means 'tilting at an angle of no more than 5° to the horizontal'. It will be understood that the distributor and the bed support could be removed together and at the same time.

Preferably, the column further comprises a locking system, the method further comprising the step of locking the adapter assembly with said locking system after lifting the adapter assembly no more than three inches or seventy six millimeters above the tube with the drive system. This provides for greater operator safety.

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According to a second aspect of the present invention, there is provided a method for conducting maintenance on a chromatography column comprising the steps of:

- a) providing a chromatography column comprising
 - a dispersion system comprising a nozzle including a mobile phase pathway connected to a liquid inlet;
 - a tube with an adapter assembly and a base assembly connected to a drive system, said adapter assembly moveable within a cavity of said tube in an operational mode;
 - the base assembly comprising a distributor and a bed support fastened to each other by releasable fixing means,
 - said drive system comprising one or more cylinders;
 - a collection system opposing the dispersion system; and one or more seals;
- b) releasing the tube from the base assembly;
- c) lifting the tube and the adapter assembly no more than three inches or seventy six millimeters above the base assembly with the drive system to provide a gap for access therebetween;
- d) unfastening the bed support from the distributor by releasing the fixing means without accessing said gap;
- e) removing the bed support from the column;
- f) conducting maintenance on the column and/or the bed support and/or said one or more seals;
- g) returning the bed support to the column and fastening the bed support to the distributor; and
- h) lowering the tube and the adapter assembly with the drive system and reconnecting the tube to the base assembly.

The gap provided for access between the tube and adapter assembly and the base assembly is no more than three inches or seventy six millimeters in height in order to permit removal of the bed support from the column or return thereto. In one aspect, the gap is no more than two inches or fifty millimeters in height to allow access to the column. In another aspect, the gap is less than two inches or fifty millimeters in height to allow access to the column. In a further aspect, the gap is less than one inch or twenty five millimeters in height. In yet another aspect, the gap is at least 0.4 inches or ten millimeters in height. Restriction of the gap height to less than three inches or seventy six millimeters prevents the operator from working beneath the raised adapter assembly and tube and thus from being physically exposed to the suspended weight.

Preferably, the fixing means are releasable from the exterior face of the distributor. This further reduces the exposure of the operator to a suspended load as they do not need to enter the gap.

Preferably, the cylinders are externally mounted to the column. This facilitates greater spacing between the cylinders. More preferably, each said cylinder is independently removable from the column.

Preferably, the distance between any two said cylinders for maintenance access is greater than the diameter of the bed support. This permits the use of a handling device to support and remove or replace the bed support and/or distributor from/to the column. Maintenance access is the access to the column and its component parts such as the bed support and/or distributor which is required in order to carry out maintenance or service.

Preferably, the step of removing the bed support is carried out without substantially tilting the bed support. This reduces operator exposure beneath the suspended load and facilitates manhandling and/or mechanical handling of the bed support. The term 'without substantially tilting' as used herein means 'tilting at an angle of no more than 5° to the horizontal'.

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Preferably, the step of removing the bed support involves use of a handling device. More preferably, the handling device comprises at least one arm and the method comprises supporting or affixing the bed support on at least one arm of the handling device. More preferably, the method comprises releasably affixing the outer rim of the bed support to at least one arm of said handling device.

Optionally the step of conducting maintenance on the column further comprises removing the distributor without substantially tilting said distributor. The term 'without substantially tilting' as used herein means 'tilting at an angle of no more than 5° to the horizontal'. It will be understood that the distributor and the bed support could be removed together and at the same time.

Preferably, the column further comprises a locking system, the method further comprising the step of locking the adapter assembly and the tube above the base assembly with said locking system after lifting said adapter assembly and the tube no more than three inches or seventy six millimeters above the base assembly with the drive system. This provides for greater operator safety.

According to a third aspect of the invention, there is provided a chromatography column comprising:

- a dispersion system and a nozzle including a mobile phase pathway connected to a liquid inlet;
- a tube with an adapter assembly and a base assembly connected to a drive system having at least one cylinder,
- said adapter assembly moveable within a cavity of said tube in an operational mode;
- the adapter assembly comprising a distributor and a bed support fastened to each other by releasable fixing means;
- the base assembly comprising a distributor and a bed support fastened to each other by releasable fixing means;
- a collection system opposing the dispersion system; and one or more seals;
- the fixing means fastening the distributor and bed support of the adapter assembly or the base assembly to each other are releasable from the exterior face of the distributor, wherein the adapter assembly is disconnectable from the tube to allow lifting by the drive system in order to provide a gap for maintenance access of no more than three inches or seventy six millimeters; and
- the tube and the adapter assembly are disconnectable from the base assembly to allow lifting by the drive system to provide a gap for maintenance access of no more than three inches or seventy six millimeters.

Preferably, the drive system comprises at least two cylinders and the distance between any two said cylinders for maintenance access is greater than the diameter of the bed support. This permits the use of a handling device to support and remove or replace the bed support and/or distributor from/to the column. Maintenance access is the access to the column and its component parts such as the bed support and/or distributor which is required in order to carry out maintenance or service.

The gap provided for access between the adapter assembly and the tube, or between the tube and the adapter assembly and the base assembly, is no more than three inches or seventy six millimeters in height in order to permit removal of the bed support and/or the distributor from the column or return thereto. In one aspect, the gap is no more than two inches or fifty millimeters in height to allow access to the column. In another aspect, the gap is less than two inches or fifty millimeters in height. In a further aspect, the gap is less than one inch or twenty five millimeters in height. In yet another aspect, the gap is greater than 0.4 inches or ten millimeters in height. Restriction of the gap height to less than three inches

or seventy six millimeters prevents the operator from working beneath the raised adapter assembly and thus from being physically exposed to the suspended weight.

Preferably, the drive means comprises at least two hydraulic cylinders and most preferably three hydraulic cylinders. Other drive means include, for example, electrical or pneumatically powered cylinders.

Preferably, the drive means is external to the column.

Preferably, the column additionally comprises a locking system for securing the raised adapter assembly above the tube and/or securing the raised tube and adapter assembly above the base assembly. This improves operator safety.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an embodiment of a column known in the art in a first maintenance position in cross sectional view.

FIG. 2 is a cross sectional view showing the same embodiment of the column of FIG. 1 in a second maintenance position.

FIG. 3 is a schematic exploded front view of an embodiment of the present invention.

FIG. 4a is a schematic front view of a column in accordance with the invention; FIG. 4b is a side sectional view of the column of FIG. 4a; and FIG. 4c is a top plan view of the column of FIG. 4a.

FIG. 5a is a front perspective view showing the adapter assembly raised and secured into position to provide a gap for access; FIG. 5b shows removal of the fastening means securing the distributor and bed support.

FIG. 6 is a perspective view of a handling device used to remove/insert a distributor or a bed support from/into a column in accordance with the invention.

FIG. 7a and FIG. 7b are perspective views of the column of FIG. 5 showing the removal of securing rods which fasten the bed support to the distributor.

FIG. 8a, FIG. 8b and FIG. 8c are perspective views showing the removal of the bed support from the column.

FIG. 9a is a perspective view of a column with an inset showing a locking system in accordance with the invention; FIG. 9b shows the column tube raised above the base and in the process of being locked into position.

FIG. 10 is a perspective view of a column with the column tube raised and locked into position in readiness for maintenance.

FIG. 11a and FIG. 11b illustrate the process of removing the bed support from the column using a handling device.

FIG. 12 shows the bed support having been removed from the column in readiness for maintenance.

FIG. 13 is a perspective view of the column of FIGS. 10 and 11 with the column tube lowered awaiting bolting to the base.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is concerned with a method and apparatus for enabling maintenance within a chromatography column. FIG. 1 shows a column 10 known in the art and described in U.S. Pat. No. 6,736,974 which permits maintenance within a chromatography column without the need for a hoist or crane. The column 10 comprises an elongated hollow cylindrical housing 12, or tube, having a dispersion system 14 at the top and a collection system 16 at the bottom. The dispersion system 14 includes a cylindrical drum 18 having an upper cylindrical plunger head or adapter 20 formed at the lower or interior end (i.e. interior to the column). The adapter 20 is normally disposed within the upper portion of tube 12 such as is illustrated in the first operational

position of FIG. 1. The adapter 20 may be moved by a drive system 34 such as the hydraulic arrangement shown in FIG. 1. The movement of the adapter 20 allows for the compression of chromatography media in order to produce a packed media bed of the optimum height within the column; a cavity 22 is formed between the dispersion and collection systems 14, 16 and/or between the adapter 20 and the base 64.

The dispersion system 14 may include a mobile phase pathway connected to a liquid inlet 24 together with an inlet manifold 26 to distribute incoming liquid throughout a top portion of a media bed contained within the cavity 22. A bed support (or inlet screen) 28 or filter is attached to the adapter 20 by connectors and/or by an inner clamp nut 30 which is accessible from the cavity 22. The bed support 28 may be removed for maintenance purposes by release of the clamp nut 30; the distributor plate 31 may also be removable (see U.S. Pat. No. 6,190,560 for a description of a distributor plate design). A drive system is used to move the adapter 20 in an operational mode. The drive system is comprised of at least one and preferably three or more, drive cylinders 34. The drive cylinders 34 move drive pistons 36 which are coupled to the drum 18. A portion of the drive pistons 36 may be threaded 38 to allow for the drive piston 36 to connect or couple to connection arms 40 at specific locations relative to the drive piston 36 such as with nuts 42, 44.

FIG. 1 shows a first maintenance position of the adapter 20 wherein the adapter 20 is raised a predetermined distance from a top 54 of the cavity 22 within the cylinder by means of the drive system 34 and piston 36. The operator is thereby provided access with a hand to the centre of the drum 18 to release or affix nut 30 which retains the distributor plate 31 and bed support 28 to the adapter 20. The distributor plate 31 and or/bed support 28 may then be removed for maintenance. These are then replaced by affixing them to the adapter 20 and the adapter 20 may be lowered to return to an operational mode, nuts 42, 44 being reset to a proper operational configuration, if necessary.

In order to perform a second maintenance operation, such as removal of the lower bed support (or screen) 160 which is typically positioned so that its outer edge 162 is between the tube 112 and the collection system 116, the tube 112 may be raised by the drive system as illustrated in FIG. 2. The bolts which normally secure the tube 112 to the base 164 are removed, and the nuts 142, 144 may be coupled to the piston 136 to drive the tube 112 along with the drum 118 upwards as shown. A gap is thus provided which allows access for an operator to loosen nut 132, which affixes the bed support 160 to the base 164, and remove the bed support 160 for maintenance. Once maintenance has been completed, the bed support 160 is replaced, affixed by nut 132 to the base 164 by the operator, and the process reversed to lower tube 112 and the drum 118 into an operational position.

The present invention will now be described with reference to FIGS. 3 to 13; FIGS. 3 to 8 relate to providing access to the upper adapter assembly and FIGS. 9 to 13 to providing access to the base assembly for maintenance.

FIG. 3 is a schematic exploded front view of a column in accordance with the invention. The column is made of strong, inert materials such as stainless steel and other materials which are suitable for use in a GMP environment typical of the pharmaceutical industry. The column 210 is supported on legs 204 having feet 206 which are adjustable in order to modify the height and/or the level of the column. The legs 204 support the column 210 which comprises a cylindrical housing or tube 212 separating a base assembly 263 at one end from an adapter assembly 215 at the other. The tube 212 may typically be made from stainless steel, or other strong, inert

materials. Adjacent to the adapter assembly **215** is a dispersion system comprising a nozzle **211** which includes a mobile phase pathway, for the introduction of buffer or other suitable mobile phase liquids or chemicals/materials to be separated, and a liquid inlet **209**. The tube **212** may be connected to the adapter assembly **215** and base assembly **263** by a drive system having one or more cylinders **234**. The drive system may be a hydraulic system, as shown, or may be powered by other suitable means, such as pneumatic or electrical means. The adapter assembly **215** is moveable within a cavity **222** of the tube **212** in an operational mode, for example, to pack or compress the bed of chromatographic media used to effect chromatographic separation of chemicals within the column. The adapter assembly **215** comprises an adapter flange **217**, one or more distance pillars **219**, a backing plate **220** made typically of stainless steel, a distributor **231** which may take the form of a plate having many channels to effect the even distribution of liquids, and a bed support **228** comprising a screen or mesh or filter and optionally a sealing ring (e.g. **229**). The bed support may be made of an inert plastic or metal material such as stainless steel. The distributor **231** and bed support **228** are fastened to each other by releasable fixing means (not shown). Typical releasable fixing means include, but are not limited to, a screw, a nut or a clamp. The fixing means (not shown) may only be accessed and thus released from the exterior face of the distributor **231** or backing plate **220**, that is the face of the plate furthest away from the cavity **222**. In the present example, the nozzle **211** must first be removed to provide access to the fixing means (not shown). Additional releasable fixing means, accessible from the exterior face of the backing plate, may optionally be employed to fasten the backing plate, distributor and bed support together. These fixing means can take the form of bolts inserted through corresponding holes around the perimeter of the components. Access from the exterior face of the backing plate or distributor avoids unnecessary exposure of the operator to a suspended or supported load within the column.

The base assembly **263** comprises a distributor **266** and a bed support **268** and optionally a backing plate **264** fastened to each other by releasable fixing means **269**. The bed support **268** comprises a screen or mesh or filter and optionally a sealing ring (e.g. **274**). The bed support may be made of an inert plastic or metal material such as stainless steel. Releasable fixing means **269** are, for example, a screw, a nut, a bolt or a clamp; it will be appreciated that other releasable fixing means are also possible. As can be seen from the figure, the fixing means **269** secures bed support **268** and the distributor **266** through a central hole in each component. The fixing means **269** is only accessible and may therefore only be released from the exterior face of the distributor **266**. In FIG. 3, nozzle **272** must first be removed to provide access to release fixing means **269**. Additional releasable fixing means, accessible from the exterior face of the backing plate, may optionally be employed to fasten the backing plate, distributor and bed support together. These fixing means can take the form of bolts inserted through corresponding holes around the perimeter of the components. Access from the exterior face of the backing plate **264** avoids operator exposure beneath a suspended load, were access only to be available from within the interior of the column.

It will be understood that separation of chemical or biological materials on the column, when the tube **212** is full of chromatographic media, can be carried out in either a downward or upward flow. Thus, in a downward flow, liquid containing chemical or biological materials to be separated is introduced through nozzle **211** and moves in a downward direction through the bed of media, to be collected in the

collection system at the base of the column via an outlet port (not shown). In upward flow mode, liquid containing materials to be separated is introduced via the bottom nozzle **272** and flows upwards through the media bed to be collected at the top of the column via an outlet port (not shown). In the interests of clarity, the maintenance or servicing of the column will be described in downward flow mode.

In order to conduct maintenance on the adapter assembly **215** or distributor **231**, the adapter assembly **215** is disconnected from the column tube **212** by unscrewing the nuts which join the adapter flange **217** to the upper column flange **213a**. The drive system then raises the adapter assembly **215** a distance of no more than three inches or seventy six millimeters, typically a distance of no more than two inches or fifty millimeters by means of cylinders **234** to allow for access to the interior of the column for maintenance or service. The adapter assembly **215** is locked into position using the locking system **270** by means of plungers **237** which are inserted through aligned holes in the cylinder bracket **236**, cylinder **234** and assembly **215**. In this secured position, the adapter bed support and/or the distributor may be removed from the column for maintenance once the fixing means are released, release being effected by removal from the exterior face of the column following removal of the nozzle **211** as described above. Once maintenance has been carried out on the column (e.g. the bed support **228** has been replaced), the column **210** is made operational again by reversing the above procedure: the adapter assembly **215** is released from its secured position by removal of the plungers **237** and lowered by use of cylinders **234** to be reconnected to the column tube **212** by replacing the nuts which join the adapter flange **217** to the upper column flange **213a**.

Maintenance or service is carried out on the bottom distributor **266** or base assembly **263** by releasing the tube **212** from the base assembly **263** and lifting the tube **212** and adapter assembly **215** a distance of no more than three inches or seventy six millimeters, typically a distance of no more than two inches or fifty millimeters, with the aid of the drive system. The bolts on the lower flange **213b** of the column tube **212** which join it to the bottom backing plate **264** are removed. The column tube **212** and adapter assembly **215** are then lifted by means of the drive cylinders **234**. The tube **212** and upper adapter assembly is secured in position by the locking system **270** above the base with the cylinder brackets **236** by inserting a plunger (not shown) through holes aligned in the locking pin **238** and bracket **236**.

The bottom nozzle **272** is then disconnected from the back plate **264** and distributor **266**. The nozzle **272** is removed together with the distance ring **235**, to allow access to release the fixing means **269** which may be in the form of a nut. The nut **269** is removed from the exterior face of the distributor **266**, i.e. the face distant from the cavity **222**, and thus eliminates operator exposure to a suspended or supported load. If additional releasable fixing means, such as bolts inserted through the backing plate, distributor and bed support as described above are present, these must be removed from the exterior face of the backing plate. The interior of the column may now be accessed for maintenance or service, such as the replacement or cleaning of the bed support **268** and/or O-rings. To return the column to an operational mode, the above procedure is reversed.

FIG. 4a is a schematic front view of a column in accordance with the invention. The column **310** is supported on legs **304** and has a base assembly **363** separated from an adapter assembly **315** by a tube **312**. These components are made of strong, inert materials which are approved for GMP within the pharmaceutical industries, such as stainless steel.

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In the figure, the base assembly **363** and adapter assembly are connected to a drive system which takes the form of three hydraulic cylinders **334**. It will be understood that in other embodiments, different drive systems may be used to raise and lower the column, such as those powered by compressed air or electricity. Furthermore, it is not essential that three cylinders are used, in some cases one being sufficient. The column **310** has a top nozzle **311** and a bottom nozzle for the introduction of liquids into the column. An electrical unit **378** for controlling the drive system is also shown.

FIG. **4b** is a side sectional view of the column of FIG. **4a** showing one of the hydraulic cylinders **334** in cross section. The cavity **322** for containing the bed of chromatographic media can be seen in cross section. The liquid inlet **305**, **375** and outlet **306**, **376** of the top **311** and bottom **372** nozzle are shown, for the introduction and removal of liquids from the column **310**. The cylinder **334** is connected to the base assembly (seen here comprising backing plate **364**, distributor **366** and bed support **368**) and the adapter assembly **315** (seen here comprising backing plate **320**, distributor **331** and bed support **328**).

FIG. **4c** is a top plan view of the column of FIG. **4a** which shows the three hydraulic cylinders **334** and nozzle **311** with liquid inlet **305** and outlet **306**.

To raise the adapter assembly **315** for maintenance purposes, the nuts under the upper column flange, which join the adapter **315** and column flange **313a**, are loosened and removed. The drive system then lifts the adapter assembly **315** a distance of no more than three inches or seventy six millimeters, typically a distance of no more than two inches or fifty millimeters, by means of the hydraulic cylinders **334**. The adapter assembly **315** is raised until holes in the cylinder bracket (not shown), hydraulic cylinders **334** and the adapter assembly **315** are aligned and locked into position with plungers (not shown) to secure the assembly in the service or maintenance position (see FIG. **3**).

FIG. **5a** is a front perspective view showing the adapter assembly **415** raised and secured into position to provide a gap **427** for access to the interior of the column for service or maintenance. The gap **427** is clearly shown in the figure for illustrative purposes but it would be no more than three inches or seventy six millimeters and typically no more than two inches or fifty millimeters in size to prevent the operator inadvertently reaching into it and exposing his/her arm to a heavy suspended load. The column **410** has a drive system comprising three hydraulic cylinders **434**. The adapter bed support **428**, the distributor **431** and the backing plate **420** are now visible; the bed support **428** can be unfastened from the distributor **431** by releasing the fixing means (not shown) without accessing the gap **427**. In order to describe this process, reference is made to FIG. **4** in that the nozzle **311** is first removed to provide access to remove the retaining nut (not shown) which secures the bed support **328** to the distributor **331** without accessing the gap **427**. The fixing nut is removed from the exterior face of the distributor **331**.

FIG. **5b** shows release of the fixing means from the backing plate **420** side of the adapter assembly using a spanner **446**. The fixing means (in the form of a retaining nut, obscured by the spanner) secures the adapter bed support to the distributor.

The bed support **428** is heavy and requires the use of a special handling device to lift it once it has been separated from the adapter assembly.

An embodiment of the handling device **580** is shown in FIG. **6**. The device **580** is in the form of a trolley or cart with a central pillar **581** supported on frame **582** having legs **583**. The device **580** is made of strong, inert materials; such mate-

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rials include, but are not limited to, stainless steel and other materials which are suitable for use in a GMP environment typical of the pharmaceutical industry. Extendable arms **585 a, b, c** project from the pillar **581** and can be raised or lowered relative to the pillar **581** by mechanical or other means. In the embodiment shown, the arms **585 a, b, c** are raised or lowered by a manual jacking mechanism (not shown) adjacent to the handle **584** which provides the means to steer or control the device. The arms **585 a, b, c** are designed to bear the weight of the distributor or bed support and are extendable to the diameter of these components. While the embodiment shown has three arms **585 a, b, c**, it will be understood that the device is not so limited and that other embodiments may have less than or more than three arms (e.g. one, two, four, five) depending on the individual design. Holes **587 a, b, c** at the extremities of the arms **585 a, b, c** are provided for bolting or securing of the distributor and/or bed support to the arms for safety, particularly during transport. Pads (not shown) may be fitted to the arms **585 a, b, c** to minimise any risk of damage to the bed support/distributor when these components come into contact with the arms. A raised, central element, **588** (typically of conical shape) for receipt of the central hole in the bed support or distributor provides a means for centralising these components on the arms **585 a, b, c** of the device **580**. This element **588** may be fitted on either, or both, the upper or under side of the point where the arms **585 a, b, c** intersect. In operation, the distributor and/or bed support is either suspended from the arms **585 a, b, c** or supported on the arms. Pivotal wheels **586** allow easy movement and manoeuvrability of the handling device **580**. In the embodiment shown, the movement of the device **580** and the raising/extension of the arms **585 a, b, c** are by manual means, but it will be understood that other embodiments are possible which incorporate powered systems (e.g. electrical, pneumatic or hydraulic systems) to drive the device **580** and lift/lower the arm **585**. It will also be understood that in other embodiments of the handling device (not shown), arm **585a** is capable of pivoting or rotation around pillar **581** to enable the arms **585 b** and **c** to access a narrow gap between any two cylinders (e.g. **434** of FIG. **5a**) and remove/insert a bed support and/or distributor which have a diameter which is greater than the distance between any two cylinders in the column (e.g. **434** of FIG. **5a**).

Other embodiments of the handling device are possible, for example in which the holes **587 b, c** are configured to align with corresponding holes in the side of the bed support or distributor when the arms **585 b, c** contact the outer rim of these components, thereby allowing affixment of the bed support or distributor to the arms simply by means of threading screws into the aligned holes.

The operation of the device **580** in removing the bed support is shown in FIGS. **7** to **9**.

FIG. **7a** and FIG. **7b** are perspective views of the column of FIG. **5** showing the handling device of FIG. **6** supporting the bed support **628** on one or more arms **685**. The arms **685** are raised into position below the bed support **628**, care being taken not to damage the bed support by positioning the pads (not shown) on the arms **685** of the handling device **680** under the outer rim of the bed support and then gently raising the arms **685** up to the bed support. Once the arms **685** are in position, the nuts on the threaded rods **633** that go through the back plate **620** and distributor **631** into the outer perimeter of the bed support **628** are loosened and the bed support can be removed on the handling device. The rods **633** are initially loosened with a spanner and finally removed by hand. As can be seen from the figures, the removal of the rods **633** is carried out from the exterior face of the backing plate **620** without

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accessing the gap and thus without exposing the operator to a suspended or supported overhead weight.

FIG. 8a and FIG. 8b are perspective views showing the removal of the bed support 728 on the handling device 780 from the column 710. In FIG. 8a the bed support 728, supported on the arms 785 of the device 780, is removed from the column 710 without substantially tilting the support 728. The device 780 can then be moved away from the column (FIG. 8b) and the arms 785 lowered in order that the bed support 728 can be cleaned or replaced. Maintenance or servicing the column may now be carried out as required. For example, the bed support 728 may be cleaned or replaced, O-rings replaced and/or the distributor 731 may also be removed for cleaning.

FIG. 8c is a perspective view showing the removal of the bed support 728 from a column 710 using a different embodiment of a handling device 780. The bed support 728 is secured or affixed to the arms 785 of the handling device 780 by inserting bolts or screws through holes 787 in the arms 785 of the handling device 780 into corresponding holes in the rim of the bed support 728.

To return to an operational mode, the above procedure is simply reversed. The bed support and/or distributor is returned to the column and affixed to each other and to the backing plate, the nozzle reattached, the adapter assembly lowered and bolted to the column tube.

Access to the bottom bed support and interior of the column will now be described with reference to FIGS. 9 to 13. To access the bottom bed support, the tube is released from the base assembly by unscrewing the bolts that join it to the base and then lifting the tube and upper adapter assembly with the hydraulic cylinders.

FIG. 9a shows a column 810 as previously described in FIGS. 3 to 5 and FIGS. 7 and 8. The bolts on the lower flange 813b of the column tube which fasten the tube 812 to the bottom backing plate 864 are loosened and unscrewed. The column tube 812 and adapter assembly 815 are lifted by the hydraulic cylinders 834 of the drive system no more than three inches or seventy six millimeters above the base assembly and secured into position by the locking system 870 (see inset of FIG. 9a showing part of the locking system) as described previously. Plungers 837 are introduced into the aligned holes in the locking pin 838 and bracket 836 to secure the tube and adapter assembly in position (FIG. 9b). After removal of the bolts securing the tube 812 to the bottom backing plate 864, maintenance can now be carried out on the column in the gap 827 created by raising the tube and adapter assembly. This gap is no more than three inches and typically no more than two inches to restrict operator access to the gap.

FIG. 10 shows the column 910 with the tube 912 raised and mechanically locked to the cylinders 934 in readiness for maintenance. The bottom nozzle (not shown—see 272 in FIG. 3) is first removed from the back plate 964 by unscrewing the retaining bolts. The retaining nut (or fixing means) which fastens the bed support 968 to the distributor 966 is released from the backing plate 964 side of the column 910. If additional fixing means are present, such as bolts (not shown) which fasten the bed support to the distributor and the backing plate, and are located on the perimeter of the backing plate, these are released from the backing plate face of the column.

The bed support 1068 can now be removed from the column by use of the handling device as shown in FIG. 11a and FIG. 11b. The handling device (as described in FIG. 6 above) 1080 is wheeled into position where the arms 1085 are no more than three inches and typically no more than two inches above the bed support 1068. The bed support 1068 has a number of threaded holes that correspond to the holes used to bolt the bed support to the backing plate 1064. The arms 1085

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of the handling device 1080 have holes through which bolts are screwed into the bottom bed support 1068; these holes are aligned to those of the bed support 1068 and bolts affixed to secure the bed support to the arms 1085. Once attached, the bed support 1068 can be removed from the column by raising the arms 1085 no more than three inches and typically no more than two inches and then wheeling the handling device 1080 away from the column 1010. It will be understood that other embodiments of handling devices, such as that described in FIG. 8c above, can be used to remove the bed support.

The bed support 1068 can now be cleaned or new O-rings replaced as necessary. Generally the bed support will be moved away from the column, as shown in FIG. 12, lowered onto a surface (such as a trolley or workbench) and released from the arms 1185 of the handling device 1180 to facilitate cleaning and servicing. The distributor (1066 in FIG. 11) can also be removed and serviced in a similar manner using the lifting device.

Once maintenance or servicing has been completed, the column is returned to an operational mode by simply reversing the process as described above. This involves replacing the bed support/and or distributor in the column, affixing the components to the backing plate, reattaching the nozzle, lowering the tube and adapter assembly. FIG. 13 shows the column 1210 of FIG. 11 connected to the hydraulic control unit 1290 with the tube 1212 lowered and ready to be bolted to the backing plate 1264.

While preferred illustrative embodiments of the present invention are described, one skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which are presented for purposes of illustration only and not by way of limitation. The present invention is limited only by the claims that follow.

What is claimed is:

1. A method for conducting maintenance on a chromatography column comprising the steps of:

- a) providing a chromatography column comprising:
 - a dispersion system comprising a nozzle including a mobile phase pathway connected to a liquid inlet;
 - a tube with an adapter assembly and a base assembly connected to a drive system, said adapter assembly moveable within a cavity of said tube in an operational mode;
 - the base assembly comprising a distributor and a bed support fastened to each other by releasable fixing means;
 - said drive system comprising one or more cylinders;
 - a collection system opposing the dispersion system; and one or more seals;
- b) releasing the tube from the base assembly;
- c) lifting the tube and the adapter assembly no more than three inches or seventy six millimeters above the base assembly with the drive system to provide a gap for access therebetween;
- d) unfastening the bed support from the distributor by releasing the fixing means without accessing said gap;
- e) removing the bed support from the column;
- f) conducting maintenance on the column and/or the bed support and/or said one or more seals;
- g) returning the bed support to the column and fastening the bed support to the distributor; and
- h) lowering the tube and the adapter assembly with the drive system and reconnecting the tube to the base assembly.

2. The method of claim 1, wherein step c) involves lifting the tube and the adapter assembly no more than two inches or

fifty millimeters above the base assembly with the drive system to provide a gap for access therebetween.

3. The method of claim 1, wherein the fixing means are releasable from the exterior face of the distributor.

4. The method of claim 1, wherein the cylinders are externally mounted to the column. 5

5. The method of claim 4, wherein each said cylinder is independently removable from the column.

6. The method of claim 1, wherein the distance between any two said cylinders for maintenance access is greater than the diameter of the bed support. 10

7. The method of claim 1, wherein the step of removing the bed support is carried out without substantially tilting the bed support.

8. The method of claim 1, wherein the step of removing the bed support involves use of a handling device. 15

9. The method of claim 8, wherein said handling device comprises at least one arm and the method comprises suspending or affixing the bed support by securing the bed support to at least said one arm of the handling device. 20

10. The method of claim 9, wherein the method comprises releasably affixing the outer rim of the bed support to the least one arm of said handling device.

11. The method of claim 1, wherein the step of conducting maintenance on the column further comprises removing the distributor without substantially tilting said distributor. 25

12. The method of claim 1, wherein the column further comprises a locking system, the method further comprising the step of locking the adapter assembly and the tube above the base assembly with said locking system after lifting said adapter assembly and the tube with the drive system. 30

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